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Abstract: This study characterises key elements of the start in elite female World Cup skeleton athletes. The top 20 female competitors in three World Cup races were video taped within a calibrated space to allow the following components of the start to be quantified: 1) acceleration (velocity at 15-m, time to 15-m), 2) capacity (time to load, total number of steps to load) and 3) load (velocity at 45-m). A correlation analysis was used to establish the relationship between variables of interest and overall start time (15-65 m). Velocity at 15-m accounted for 86% of the variance in overall start time at St. Moritz and 85% at Sigulda. A stepwise regression analysis revealed that ~89% of the variation in start time could be explained by velocity at 15-m, time to load and the velocity at 45-m. These data indicate that rapid acceleration to attain a high velocity at 15-m is the most important component of a fast overall start time of the variables analyzed in this study. The importance of the time to load and velocity at 45-m vary according to the different track characteristics.

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Running Title: Skeleton Start in Women’s World Cup

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ABSTRACT

This study characterises key elements of the start in elite female World Cup skeleton athletes. The top 20 female competitors in three World Cup races were video taped within a calibrated space to allow the following components of the start to be quantified: 1) acceleration (velocity at 15-m, time to 15-m), 2) capacity (time to load, total number of steps to load) and 3) load (velocity at 45-m). A correlation analysis was used to establish the relationship between variables of interest and overall start time (15-65 m). Velocity at 15-m accounted for 86% of the variance in overall start time at St. Moritz and 85% at Sigulda. A stepwise regression analysis revealed that ~89% of the variation in start time could be explained by velocity at 15-m, time to load and the velocity at 45-m. These data indicate that rapid acceleration to attain a high velocity at 15-m is the most important component of a fast overall start time of the variables analyzed in this study. The importance of the time to load and velocity at 45-m vary according to the different track characteristics.

184 Words

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INTRODUCTION

Skeleton is an individual Olympic sliding sport performed on an iced bobsleigh track. The athlete begins a run by sprinting in a bent over position for the initial 20-35 m of the track before loading on the sled in a prone head-first position (Figure 1). During World Cup Competition, all competitors participate in the first run; however, only the fastest 20 finishers proceed to a second run. This race format ensures both runs are performed within 3 h and involve a maximal effort. The winner is determined by the lowest accumulated time over the two runs.

Preliminary evidence suggests that the start time (15-65 m) is an important factor in determining overall skeleton performance with the start explaining 23% and 40% of the variance in overall performance for women and men respectively (Zanoletti et al., 2006). It is suggested that a fast start time is a prerequisite for a successful performance (Zanoletti et al., 2006). The overall start time reflects the ability of the athlete to 1) accelerate the sled 2) run with the sled and 3) load the sled. The start time does not include the first 15-m of acceleration (Figure 1); however, this phase of the start may differentiate great starters from good starters. Since skeleton has become an Olympic sport, many countries have undertaken talent identification and talent transfer initiatives to increase their chances of international success. Often the main selection criteria for recruiting athletes into skeleton are a fast upright 30-m sprint time. Short sprint speed becomes a screening variable based on the understanding that an already fast athlete may quickly become a fast starter.
and thus a great performer in the sport of skeleton (OWIA, 2006; BBSA, 2007; BCS, 2007).

Analysing the skeleton push during World Cup competition provides a unique opportunity to understand the complex demands of elite skeleton starts and identify critical events which are often referred to as ‘performance indicators’ (Nevill et al., 2002). From competition analysis, the coach can enhance the training environment to facilitate learning (Hughes and Bartlett, 2002). Performance analysis allows scientists to assess an athlete’s current ability, investigate parameters that will enhance performance, gain insight into the cause and effect relationships, document ‘world’s best practice’ and identify minimum standards for elite level success. Where possible, all relevant details of performance should be collated prior to preparing any corrective actions (Franks and Goodman, 1986). External validity is an important factor in performance analysis and requires access to actual or simulated competition with athletes sampled from the population of interest. Unfortunately, optimisation of external validity can impact negatively on internal validity due to reduced control over extraneous variables in real life settings (Atkinson and Nevill, 2001). Competition represents a unique experience for most athletes, and understanding the demands of competition help direct athletic training (Foster et al., 1993).

Skeleton is an Olympic sport still in its infancy. It is therefore possible that the start will become increasingly important as more competitors develop exceptional driving skills and use state-of-the-art equipment. To the authors
knowledge, only two studies have been published on skeleton (Sands et al., 2005; Zanoletti et al., 2006) and although both highlight the importance of the start, neither address characteristics of a fast start. The primary purpose of this study was to evaluate how important different components of the start were for producing a fast start on different international tracks during elite competition. These data will extend findings previously explored by Zanoletti and colleagues (Zanoletti et al., 2006) This research is directly relevant to coaches who are encouraging the use of sprint tests for screening new recruits into the sport of skeleton and are interested in training skeleton athletes to become better starters (OWIA, 2006; BBSA, 2007; BCS, 2007).

METHODOLOGY

Subjects
Data were collected at three Women’s World Cup races during the 2005–2006 season. Lake Placid was chosen for its long, flat start, Sigulda for its short, steep start and St. Moritz because the proximity of the first curve is close to the start which could possibly influence some key aspects to the start. Athletes who placed in the top-20 and had two competition runs were included in this study. The countries these athletes represent included Canada, United States of America, Great Britain, Australia, Germany, Switzerland, Japan, New Zealand, Norway, Italy and Russia. Ethics approval for this study was obtained from Charles Sturt University (Bathurst, New South Wales, Australia) and the Australian Institute of Sport Research Ethics Committees.
Athletes

Two athletes’ performances were excluded because their sled runners came out of the groove during the push at St. Moritz. One athlete was excluded at Lake Placid and one at Sigulda because the video footage was not clear enough to pick out all of the required variables for the analysis. The total number of athlete analysed at each track was: Lake Placid n=20; Sigulda n=19 and St. Moritz n=17. Nine athletes made the top-20 on all three tracks, a further nine athletes made the top-20 twice and ten athletes made the top-20 once.

Push Characteristics

The two-handed push was used 60% of the time at St. Moritz, 40% at Sigulda and 50% at Lake Placid. Of the top six fastest starters on each track, at least four executed a one-handed push for each race. Alternatively, the two-handed push dominated in the slowest six starters with five of these athletes always using the two-handed push.

Start Analysis

For the purpose of this study, the push phase started when the athlete initiated their first step and ended once the athlete initiated the load onto the sled. Thus, the push phase time was described how long it took from the start block toe-off of the rear foot until the loading foot toe-off. Stationary digital video cameras (Sony DSR - PDX10P, Sony Australia) were set to record movement and eventually calculate the velocity of the sled over 1.6 m, immediately prior to 15-m and 45-m from the start block to determine velocity
at that point (Figure 1). The camera was tilted such that the horizontal axis of
the screen was parallel to the track slope. The video cameras recorded at a
frame rate of 50 Hz with the shutter speed set at 1/600 s and exposure set on
automatic. The viewing area of the camera was calibrated using a 2-m pole
with alternate black and white segments of 0.2 m. The pole was filmed in
positions over which the sled runners would pass regardless of the groove
used. The video of the calibration pole and sled movement was captured
using Swinger Pro 2.0 (Webbsoft Technologies, Australia). Calculation of
velocity involved the comparison of the ratio of horizontal screen pixels
representing 1.6 m (calibration pole length) with the pixels the sled moved
through during seven frames (0.14 s). Error of this digitizing process was 0.03
m/s. The correlation of the aforementioned method of measuring mean
velocity over a defined distance when compared with the mean velocity
determined from 100Hz LaVeg data (laser) over similar distances for upright
running produced similar results (r=0.90) with no noticeable bias (AIS Doug
Rosemond, Unpublished data). Because of a technical failure with the
camera, no data were collected for the velocity at 15-m at Lake Placid.

The number of steps, time to 15-m, time to load, and start technique were
assessed using a similar camera as described above. This camera was lined
up with the first set of timing lights to reduce parallax error when determining
the time taken to 15-m. This panning camera recorded movement of the
athlete from initial movement (toe-off) off the start block through to the
athlete’s completion of loading. The video capture process was the same as
above. The time to 15-m was determined from the time of the start block toe-
off to the time the front of sled to reached the 15-m position. Fifteen meters was chosen to compare performance variables as this is a known point on the track and is also the official start of the run (see Figure 1). Time to load was also determined from the time of the start block toe-off to toe-off of the last contact prior to load. Time was interpolated within a video frame rate of 0.02 s for both flight and contact time to 0.01 s. **Start time and finish times were taken from the official website** (FIBT, 2007).

**Data Analyses**

All analyses were performed using Statistica for Windows version 5.5 (StatSoft Inc., Tisa, USA). Pearson correlations were used to describe the relationship between different components of the start and overall start time for all the top 20 athletes at the World Cup Competition and **look at the association between official start and finish time**. The correlation descriptors used were 0.0 - 0.1 trivial, 0.1 - 0.3 small, 0.3 - 0.5 moderate, 0.5 – 0.7 large, 0.7 – 0.9 very large and 0.9 – 1.0 nearly perfect (Hopkins, 2004). Results are expressed as mean ± SD. **Because of the uneven number of athletes for each track, the nine athletes who were in the top-20 in all three races were used for a pairwise comparison to compare** individual variable characteristics against other tracks (Hopkins, 2003).

For the stepwise regression the dependent variable was the **start** time. We chose to use on variable that represented the acceleration phase of the push (velocity at 15-m), one variable that represented how long athletes pushed the sled for (time to load) and one variable following the load (velocity at 45-m).
Four models were used, model 1 included only 15-m velocity; model 2, 15-m velocity and time to load; model 3 was the same as model two with the addition of velocity at 45-m. Because we did not have the velocity at 15-m for Lake Placid we created model 4 which used time to 15-m, time to load and velocity at 45-m to see how the results compared to model 3. The statistical significance level was set at $p<0.05$ and correlation coefficients were interpreted as effect sizes.

**RESULTS**

**Start Time**

The mean start times for each track are presented in Table 1. Sigulda had the fastest start time followed by Lake Placid and then St. Moritz.

**Time to 15-m and Time to Load**

The mean time to 15-m was significantly greater at Sigulda compared to Lake Placid and St. Moritz (Table 1). The correlation coefficient between time to 15-m and start time was ‘very large’ at Lake Placid and St. Moritz and ‘large’ at Sigulda (Figure 2). The mean time to load was significantly shorter at St. Moritz compared to Lake Placid and Sigulda (Table 1). The time to 15-m had a ‘very large’ correlation with the velocity at 15-m at both Sigulda and St. Moritz (Figure 3).

The start time and time to load had a ‘small’ correlation at Lake Placid ($r=0.11$) and Sigulda ($r=0.14$) and ‘small to moderate’ correlation at St. Moritz ($r=0.30$). The time to load had a ‘very large’ correlation with number of steps
taken at St. Moritz ($r=0.82$), ‘large’ at Lake Placid ($r=0.67$) and Sigulda ($r=0.66$).

### 15-m and 45-m Velocity

The velocity at 15-m was significantly higher at Sigulda compared to St. Moritz (Table 1). The correlation coefficient between the velocity at 15-m and start time was ‘nearly perfect’ at Sigulda and St. Moritz (Figure 4a). The velocity at 45-m was significantly lower at St. Moritz compared with Lake Placid and Sigulda (Table 1). The correlation coefficient between the velocity at 45-m and start time was ‘nearly perfect’ at Lake Placid and ‘very large’ at Sigulda and St. Moritz (Figure 4b). The correlation coefficient between the velocity at 15-m and the velocity at 45-m was ‘very large’ at Sigulda ($r=0.71$) and ‘large’ at St. Moritz ($r=0.67$).

### Number of Steps

The number of steps until load was less at St. Moritz (14) compared to both Lake Placid (18) and Sigulda (17) (Table 1). The start time and number of steps had a ‘moderate’ correlation at Lake Placid ($r=-0.45$) and Sigulda ($r=-0.41$) and small ($r=-0.11$) at St. Moritz.

### Finish Time

The correlation coefficient between start time and finish time was ‘large’ at Lake Placid ($r=0.51$), ‘trivial’ at Sigulda ($r=0.03$) and ‘small’ at St. Moritz ($r=0.14$).
Prediction of Start Time

In the stepwise linear regression when the velocity at 15-m was considered on its own (model 1) and accounted for over 80% of explained variance at Sigulda and St. Moritz (Table 2). The second model used both the time to load and velocity at 15-m. The explained variances in model two increased by 3% at Sigulda, but no changes were found at St. Moritz. The third model accounted for velocity at 15-m, time to load and the velocity at 45-m and noted a 4% increase in explained variance at St. Moritz but only a 1% increase at Sigulda.

Because we did not have velocity at 15-m at Lake Placid we could not include that track in the above analysis. A further analysis was done (model 4) which substituted the velocity at 15-m with time to 15-m as these two variables had a ‘large to very large’ correlation. Using this method, 86% of the explained variance in start time was explained. However, the other two tracks experienced a decrease in explained variances compared to the original model of velocity at 15-m, time to load and velocity at 45-m (Sigulda 20% decrease; St. Moritz 12% decrease).

DISCUSSION AND IMPLICATIONS

The velocity at 15-m, velocity at 45-m and time to load sled explained over 85% of the start time at St. Moritz and Sigulda. Within the same analysis, the velocity at 15-m accounted for over 80% of the variance. The results of this study suggest that the athletes ability to accelerate a sled over 15-m to attain
a high velocity at 15-m is very important for achieving a fast start time. The fastest starting athletes in these races had a preference for one-handed starts. However, the data does not support the notion that the one-handed push is faster as no comparative within-athlete data exist.

*Velocity at 15-m and Time to 15-m*

The velocity at 15-m correlated highly with start time which emphasizes the importance of acceleration during the first 15-m to achieve a high velocity at 15-m and consequently a fast overall start time. These data support previous findings which indicate that rapid acceleration is a prerequisite for a good start time (Zanoletti *et al.*, 2006). The correlations between time to 15-m and velocity at 15-m were not ‘perfect’ suggests that variation exists in the acceleration profiles of the first 15-m for some elite female World Cup athletes achieving the same 15-m velocity. According to the international skeleton rules (FIBT, 2007), the initial 15-m of each track must have a 2% gradient (see Figure 1); however, after this point, the gradient and topography is unique for each track. Tracks with a relatively flat start gradient, such as Lake Placid diminish the potential for high maximal velocities, thus the push velocity may plateau early in the push phase just prior to loading. In contrast, tracks with a steeper start gradient (Sigulda) could allow athletes to continue to accelerate past 15-m to achieve a higher maximal velocity due to the increased assistance from gravity. Unfortunately we were unable to accurately quantify the start gradient due to restraints in data collection and track access. These results imply that measures of acceleration and speed can be used to identify athletes who possess the ability to accelerate as fast
as possible. Similarly, these findings can be used to influence training practices by the inclusions of acceleration training.

Time to Load and Number of Steps

The unique characteristics of each track could determine the maximum number of steps an athlete can take before loading onto the sled. Although not significantly different, athletes at St. Moritz took fewer steps until the load than those at Lake Placid and Sigulda. We observed that the length of the grooves that are cut into the track can change between tracks. At St. Moritz it appeared that the distance the cut grooves covered was less than Lake Placid and Sigulda possibly due to the close proximity of the first curve to the start at St. Moritz. This may account for the fewer number of steps prior to loading and decreased time to load at St. Moritz and the lower velocity at 15-m. Although gradient was not measured in this study, Sigulda was observed to have a lot steeper start than Lake Placid which could potentially affect the number of steps an athlete takes.

45-m Velocity

By 45-m all athletes were in a prone aerodynamic position. The velocity at 45-m was lower at St. Moritz than both Lake Placid and Sigulda. This could be a function of the amount of steps taken and the time to load being shorter therefore the athlete was unable to accelerate the sled for as long. The high correlation between start time and the velocity at 45-m suggests that the fastest starters tended to maintain a higher velocity through 45-m on all three tracks. Technique differences between athletes for high speed running and
loading the sled could explain why the velocity at 15-m is not perfectly correlated to the velocity at 45-m. About 50% of explained variance at Sigulda and 45% of explained variance at St. Moritz for the velocity at 45-m could be attributed to the velocity at 15-m. At present the velocity profile of the athlete between 15 and 45-m remains unknown. Some of the unexplained variance could potentially be due to loading on the sled which occurs between the 15-m and 45-m or the ability of the athlete to perform over-speed running on the slope. Although the load is a major component of the start, we have not been able to directly quantify the contribution of the load to start time. The stepwise regression analysis was not noticeably improved by adding in the velocity at 45-m.

Start Time and Finish Time

The lower correlation coefficients found in this study compared to previous findings (Zanoletti et al., 2006) could question the importance of the start as a performance indicator in skeleton. In this study three elite women’s races were evaluated. Zanoletti and colleagues (Zanoletti et al., 2006) studied 24 races for each gender and included elite and sub-elite competitors on different tracks over two seasons.

The merit of a fast start performance may not be directly reflected in the finish performance using the correlation method. The race is won by the slider with the highest mean velocity. The results from this study emphasize the importance of a fast acceleration during the first 15-m to attain a high velocity at 15-m, and subsequently the velocity at 15-m influenced the velocity at 45-m.
and the velocity at 45-m to subsequent split times (e.g., interval 2 and 3). Thus, the very large and moderate correlations between the velocity at 45-m and the initial split times on each track could support the notion that a fast push is not only needed to achieve a good maximal velocity at the start but also contributes to performance times over the first third of the course.

The fastest pushers were 0.24 – 0.42 s faster during the 15-65 m interval time compared with their slower counterparts on the three tracks. Often races are won by tenths of a second thus any gains that can be made at the start of the track could influence overall placing and differentiate the performance outcome between athletes with similar sliding ability. On certain tracks the start time only had a trivial or small impact on overall performance but a fast push could differentiate athletes of similar sliding ability. Support for the selection of athletes with a fast upright running speed was demonstrated in national USA skeleton team members (Sands et al., 2005). These 14 elite skeleton athletes were able to achieve 75% and 85% of their upright sprint times while pushing a sled in a crouched position on an outdoor concrete push track (at 15-m and 30-m respectively) (Sands et al., 2005). These findings suggest that a good start time maybe a prerequisite for performance on some tracks but the ability to drive the sled down the course, reduce air drag and select equipment that results in low ice friction could be equally or more important for success.

Conclusion
The aim of this study was not to predict overall race performance, rather to understand the qualities needed to become a world class starter in elite women’s skeleton. We attempted to quantify the acceleration phase, the high speed running phase and the loading phase of the start using video analysis techniques. These data suggests that the importance of each phase of the start can be different on different tracks. On all tracks the velocity at 15-m is important for a fast start time which suggests that measures of acceleration and speed can be used to identify athletes who possess the ability to accelerate as fast as possible. Similarly, these findings can be used to influence training practices by the inclusions of acceleration training. For the three tracks used for our study the strength of the relationship was less than described previously. Although a good start time maybe a prerequisite for performance on some tracks, on other tracks used on the World Cup circuit, the ability to drive the sled down the course, reduce air drag and select equipment that results in low ice friction could be equally or more important for success.

ACKNOWLEDGEMENTS

Special thanks to Dr. Jason Gublin, Acting High Performance Manager of the Australian National Skeleton Program and the Australian National Talent Identification Coordinator for his tremendous support both financially, logistically and technically.
Table 1: Mean ± SD, time to 15-m, time to load, velocity at 15-m, velocity at 45-m and the number of steps.

<table>
<thead>
<tr>
<th></th>
<th>Lake Placid</th>
<th>Sigulda</th>
<th>St Moritz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start time (s)</td>
<td>5.58±0.11</td>
<td>5.32±0.10</td>
<td>5.71±0.08</td>
</tr>
<tr>
<td></td>
<td>(^1p&lt;0.001**)</td>
<td>(^1p&lt;0.001**)</td>
<td>(^2p&lt;0.001**)</td>
</tr>
<tr>
<td>(T_{15}) (s)</td>
<td>2.75±0.09</td>
<td>2.80±0.07</td>
<td>2.75±0.07</td>
</tr>
<tr>
<td></td>
<td>(^1p=0.02^*)</td>
<td>(^1p=0.80)</td>
<td>(^2p=0.001^*)</td>
</tr>
<tr>
<td>(T_L) (s)</td>
<td>4.38±0.24</td>
<td>4.27±0.20</td>
<td>3.60±0.15</td>
</tr>
<tr>
<td></td>
<td>(^1p=0.36)</td>
<td>(^1p&lt;0.001**)</td>
<td>(^2p&lt;0.001**)</td>
</tr>
<tr>
<td>(V_{15}) (m/s)</td>
<td>6.77±0.12</td>
<td>6.71±0.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(^2p=0.01^*)</td>
<td>(^2p=0.01^*)</td>
<td></td>
</tr>
<tr>
<td>(V_{45}) (m/s)</td>
<td>11.44±0.21</td>
<td>11.27±0.18</td>
<td>10.97±0.43</td>
</tr>
<tr>
<td></td>
<td>(^1p=0.01^*)</td>
<td>(^1p=0.001^*)</td>
<td>(^2p=0.04^*)</td>
</tr>
<tr>
<td>Number of Steps</td>
<td>18±1</td>
<td>17±2</td>
<td>14±1</td>
</tr>
<tr>
<td></td>
<td>(^1p=0.30)</td>
<td>(^1p&lt;0.001**)</td>
<td>(^2p&lt;0.001**)</td>
</tr>
</tbody>
</table>

\(^1p=\text{comparison to LPL}; \ ^2p=\text{comparison to SIG}\)

\(T_{15}\) is time to 15-m, \(T_L\) is time to load, \(V_{15}\) is velocity at 15-m, \(V_{45}\) is velocity at 45-m

\(^*p<0.05; \ **p<0.001\)
Table 2: The Beta coefficients for the stepwise regression analysis and the corresponding adjusted $R^2$ between push time, velocity at 15-m, time to load, velocity at 45-m and time to 15-m.

<table>
<thead>
<tr>
<th>Model</th>
<th>Independent Variable</th>
<th>Sigulda</th>
<th>St Moritz</th>
<th>Lake Placid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Velocity at 15m</td>
<td>-0.92*</td>
<td>-0.93*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adjusted $R^2$</td>
<td>0.84</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Velocity at 15-m/</td>
<td>-0.99*</td>
<td>-0.96*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time to Load</td>
<td>-0.19*</td>
<td>-0.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adjusted $R^2$</td>
<td>0.87</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Velocity at 15m/</td>
<td>-0.86*</td>
<td>-0.78*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time to Load/</td>
<td>-0.14*</td>
<td>-0.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Velocity at 45-m</td>
<td>-0.15</td>
<td>-0.27*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adjusted $R^2$</td>
<td>0.88</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Time to 15-m/</td>
<td>0.33*</td>
<td>0.54*</td>
<td>0.29*</td>
</tr>
<tr>
<td></td>
<td>Time to Load/</td>
<td>0.82*</td>
<td>-0.05</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Velocity at 45-m</td>
<td>-0.64*</td>
<td>-0.52*</td>
<td>-0.73*</td>
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<tr>
<td></td>
<td>Adjusted $R^2$</td>
<td>0.68</td>
<td>0.78</td>
<td>0.86</td>
</tr>
</tbody>
</table>

* $P<0.05$ for Beta Coefficient

Adjusted $R^2$ values were all $P<0.001$. 
REFERENCES


  

  

  


Statistical methods for analysing discrete and categorical data recorded  

OWIA (2006). Olympic winter institute of Australia: Do you have a need for speed? 


FIGURE LEGENDS

Figure 1: Schematic diagram of the skeleton start

Figure 2: Relationship between Time to 15-m and Start time.

Figure 3: Relationship between Time to 15-m and 15-m velocity.

Figure 4a: Relationship between 15-m velocity and Start time.

Figure 4b: Relationship between 45-m velocity and Start time.